Digital System Design EC 503

Melay and Moore Models

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Mealy and Moore Model

- Finite State Machine(FSM): A FSM is a machine that has many states and has a logical way of changing from one state to the other under guiding rules.
- Types of FSM :

  Finite State Automata – With output

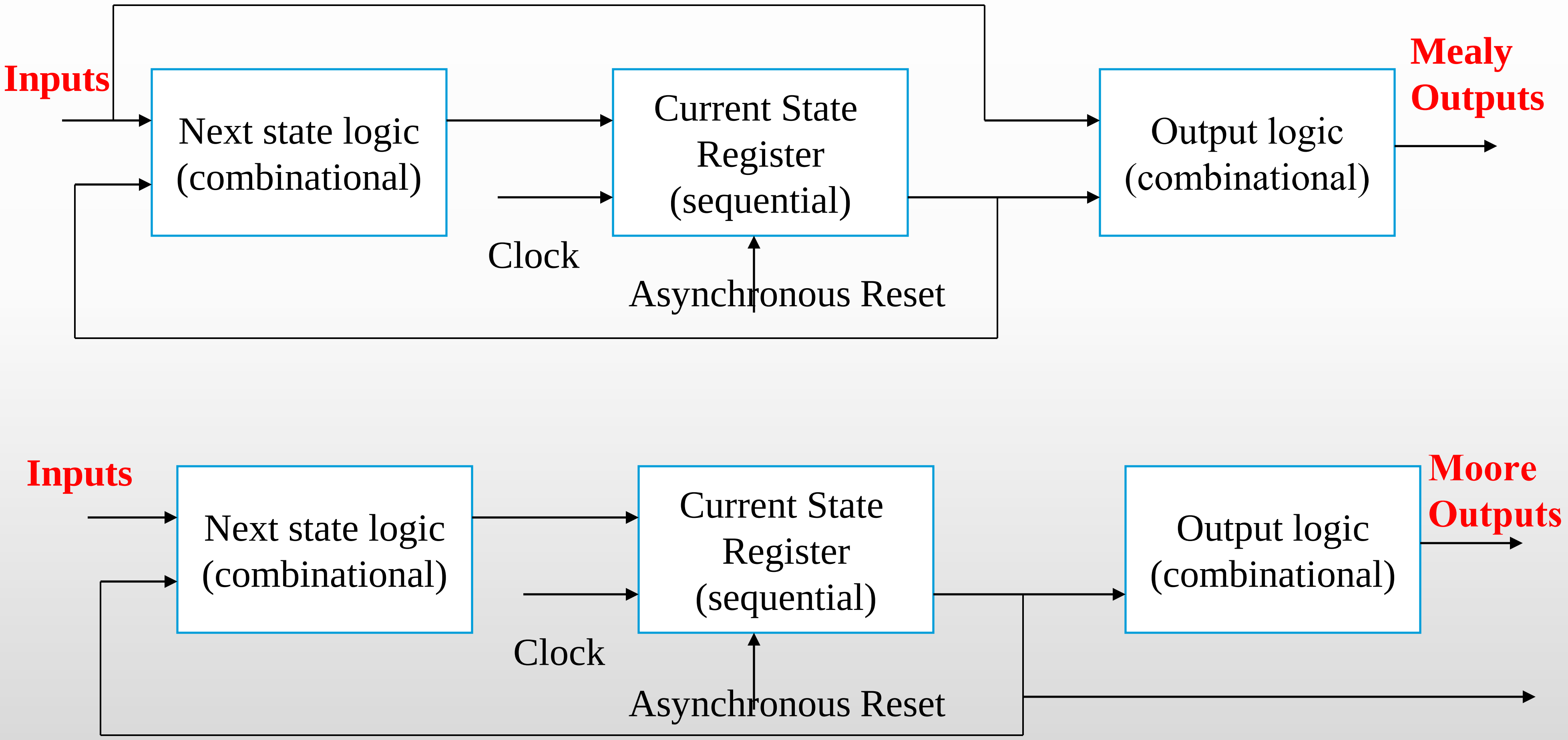
  Mealy Machine- output on transition

  Moore Machine – output on state
- **Mealy Machine** the value of output function is depend the present state and present input.
- Mealy machine is described by 6-tuples - $(Q, \Sigma, \Delta, \delta, \lambda, q_0)$
- Q = Finite non-empty set of states;

  Σ = Set of input alphabets.

  Δ = Set of output alphabets.
- δ = Transitional function mapping $Q \times \Sigma \rightarrow Q$
- λ = Output function mapping $Q \times \Sigma \rightarrow \Delta$
- q0 = Initial state.

Mealy Machine/Moore Machine



State Diagram of Mealy Machine

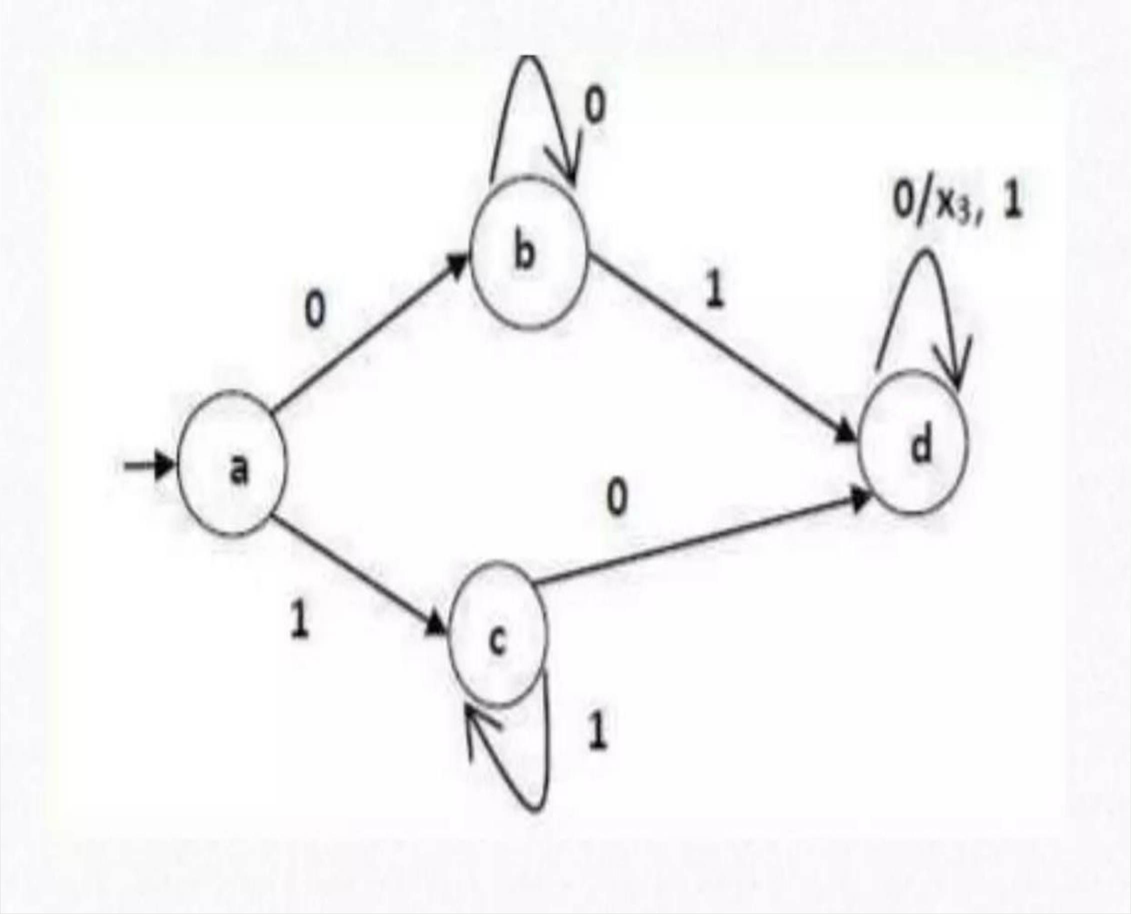


Fig : State Diagram of Meay machine

Present State	Next State			
	a = 0		a = 1	
	State	Output	State	Output
-> q0	q3	0	q1	1
q1	q0	1	q3	0
q2	q2	1	q2	0
q3	q1	0	q0	1

Fig : Transition table of Mealy

Moore Machine

- In Moore machine. the value of output function is depend on the present state only.
- Moore machine is described by 6-tuples - $(Q, \Sigma, \Delta, \delta, \lambda, q\,0)$
- where
- Q = Finite non-empty set of states;
  Σ = Set of input alphabets.
  Δ = Set of output alphabets.
- δ = Transition function mapping $Q \text{ X } \Sigma \rightarrow Q$
- λ = Output function mapping $Q \rightarrow \Delta$
- q0 = Initial state.

Moore Transition Table

- There is no concept of final state in Moore machines , we consider output for each state.

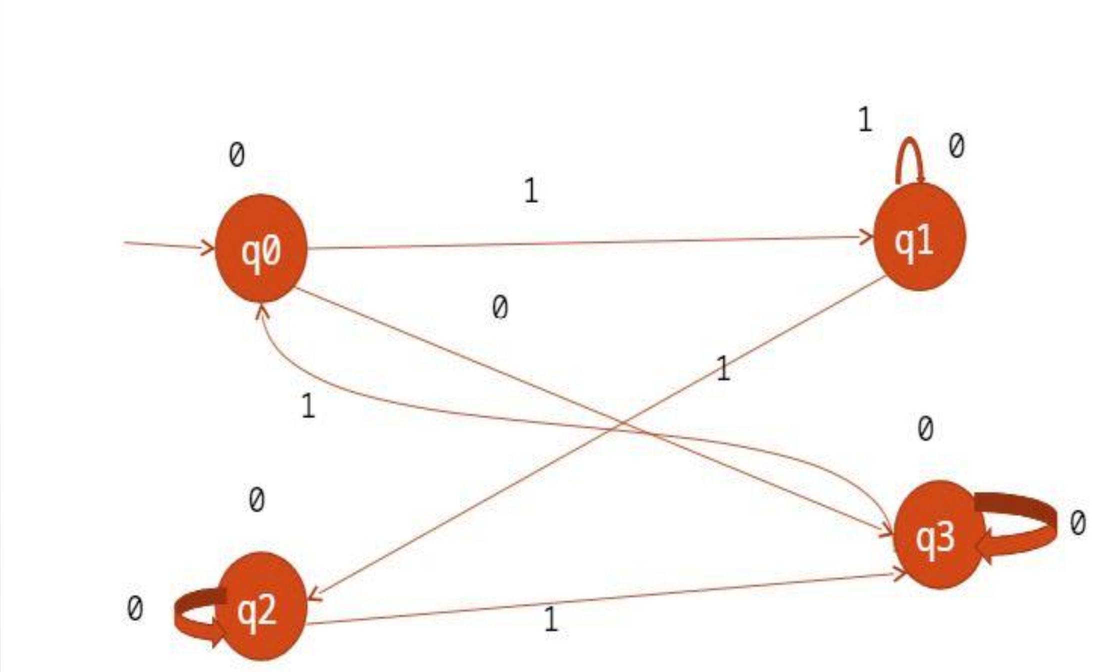


Fig : State diagram of Moore

Present State	Next State		Output
	a = 0	a = 1	
-> q0	q3	q1	1
q1	q0	q3	0
q2	q2	q2	0
q3	q1	q0	1

Fig : Transition Table of Moore

Difference Between Mealy and Moore Machines

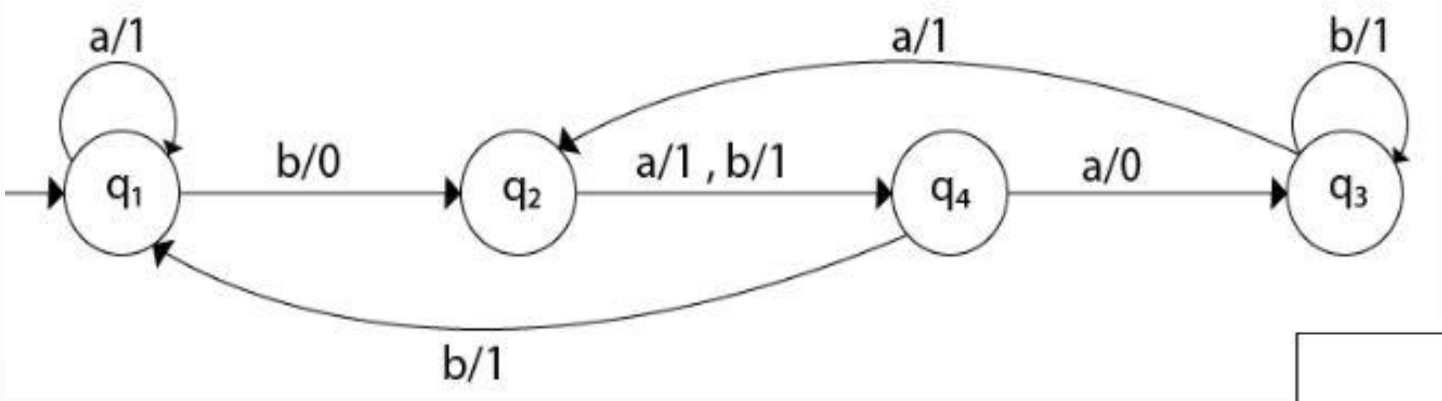
- In Mealy machine output function Z(t) depends on both the present state q(t) and the present input both the present state q(t) and the present input x(t).
- The expression for Mealy machine is $Z(t) = \lambda [q(t),x(t)]$, λ = output function
- In Moore machine output function Z(t) depends only on the present state and is independent of only on the present state and is independent of the current input. the current input.
-

  The expression for Moore machine is is $Z(t) = Z(t) = \lambda [q(t)]$.

Conversion of Mealy to Moore Machine

- Input: Melay , Output: Moore
- Step 1: Calculate the number of different outputs for each state(Qi) that are available in the state table of the Mealy machine.
- Step 2: If all the outputs of Qi are same, copy sate Qi. If it has n distinct ouputs, break Qi into n states as Qin where n= 0,1,….
- Step2: If the output of the initial state is 1, insert a new initial state at the beginning which gives 0 output.

Example of converting Mealy to Moore



Present State	Next State			
	a		b	
	State	O/P	State	O/P
q_1	q_1	1	q_2	0
q_2	q_4	1	q_4	1
q_3	q_2	1	q_3	1
q_4	q_3	0	q_1	1

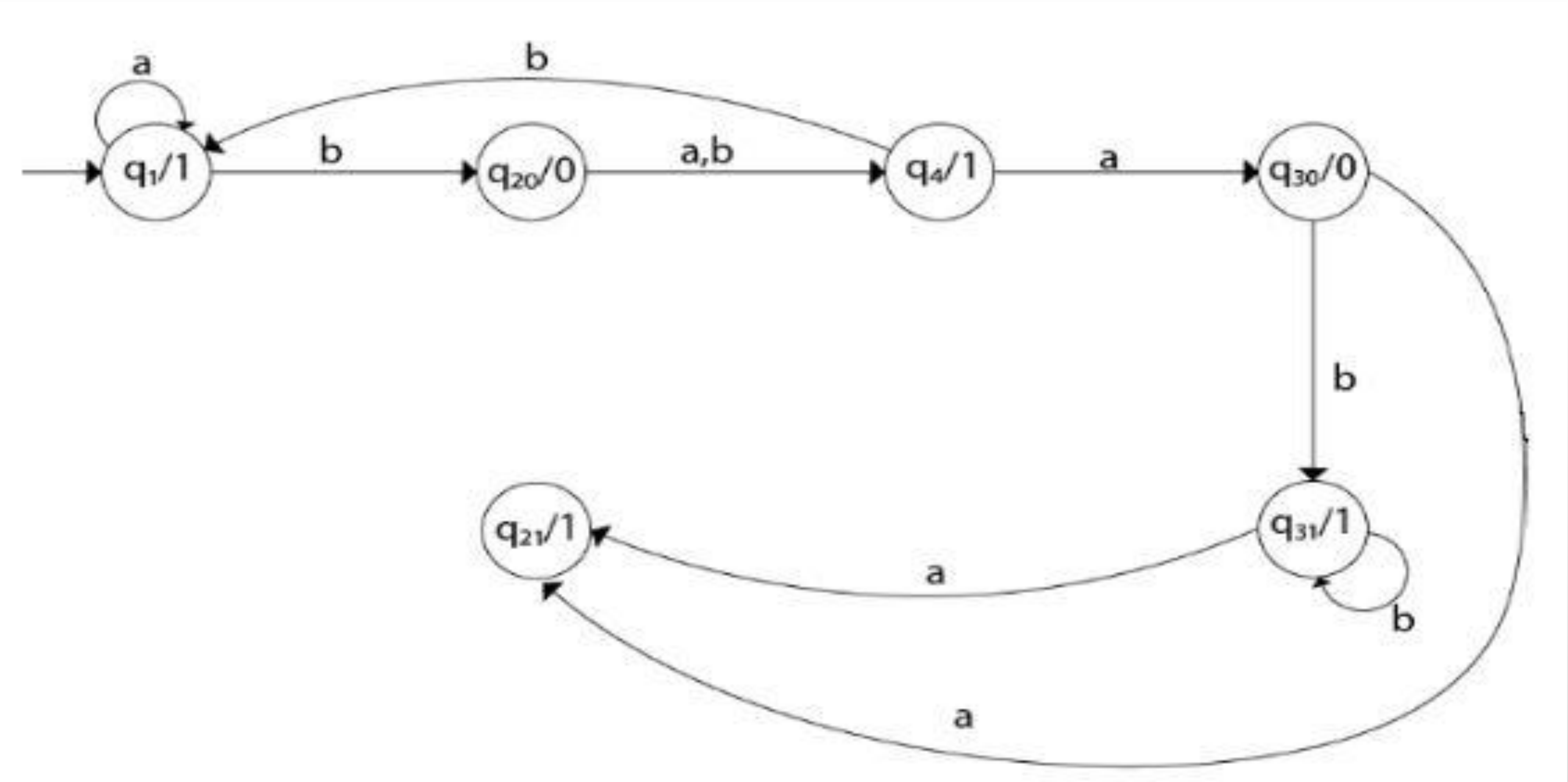
Fig: Transition table of Mealy

- For state q1, there is only one incident edge with output 0. So, we don't need to split this state in Moore machine.
- For state q2, there is 2 incident edge with output 0 and 1. So, we will split this state into two states q20(state with output 0) and q21(with output 1).
- For state q3, there is 2 incident edge with output 0 and 1. So, we will split this state into two states q30(state with output 0) and q31(state with output 1).
- For state q4, there is only one incident edge with output 0. So, we don't need to split this state in Moore machine.

Present State	Next State		Output
	a=0	a=1	
q_1	q_1	q_2	1
q_{20}	q_4	q_4	0
q_{21}	ø	ø	1
q_{30}	q_{21}	q_{31}	0
q_{31}	q_{21}	q_{31}	1
q_4	q_3	q_4	1

Fig : Transition table for Moore

Transition diagram for Moore machine



Conversion of Moore to Mealy Machine

- Input: Moore, Output: Mealy
- Step 1: Take a blank Mealy transition of table format
- Step 2: Copy all the Moore machine transition state into this table format.
- Step 3: Check the present states and their corresponding outputs in the Moore Machine state table, if for a state Qi outputs if m, copy it into the output columns of the Mealy Machine state table wherever Qi appears in the next state.

Example: Conversion of Moore to Melay

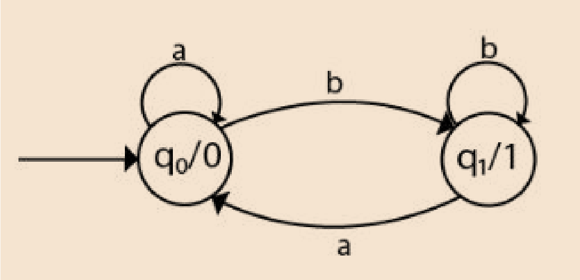


Fig: Moore Machine

Q	a	b	Output(λ)
q0	q0	q1	0
q1	q0	q1	1

Fig: Transition table of Moore

Q \ Σ	Input 0		Input 1	
	State	O/P	State	O/P
q_0	q_0	0	q_1	1
q_1	q_0	0	q_1	1

Fig: Transition table for Mealy machine

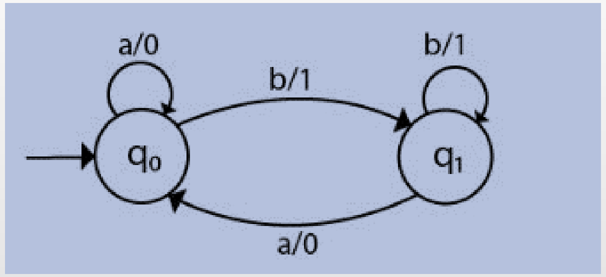
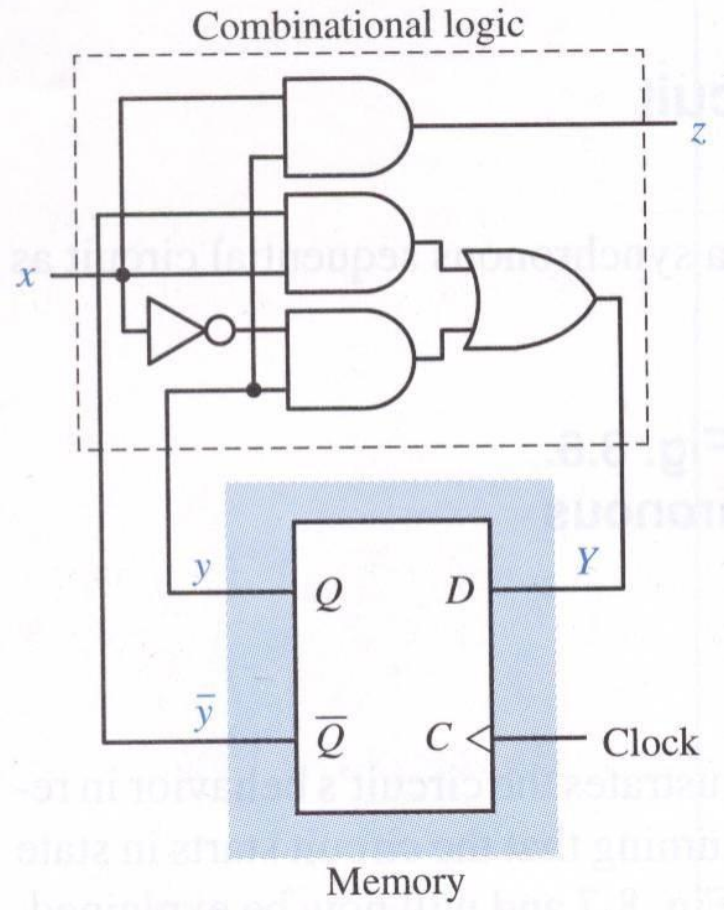
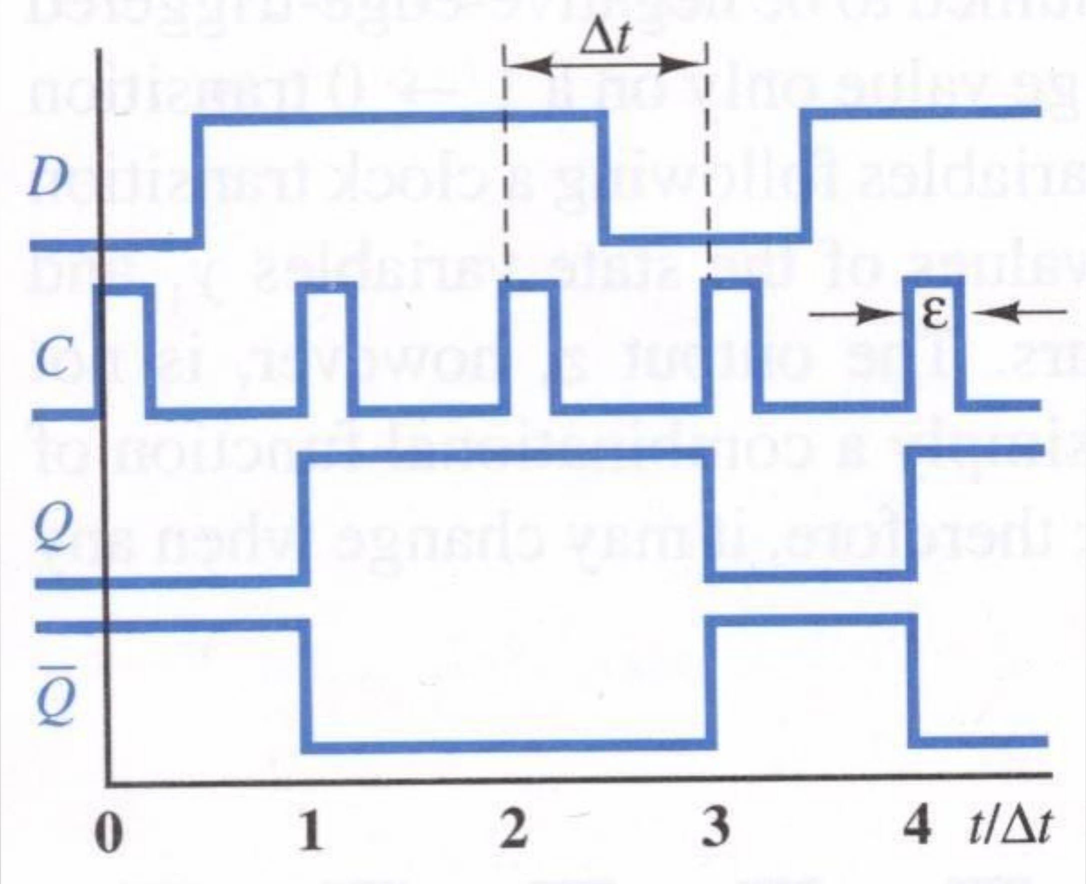


Fig: Mealy Machine

Analysis & Synthesis of Synchronous Sequential Circuits

- Analysis of logic diagrams of sequential circuits
  - Inputs, state variables, outputs, logic equations ?
  - Mealy or Moore type?



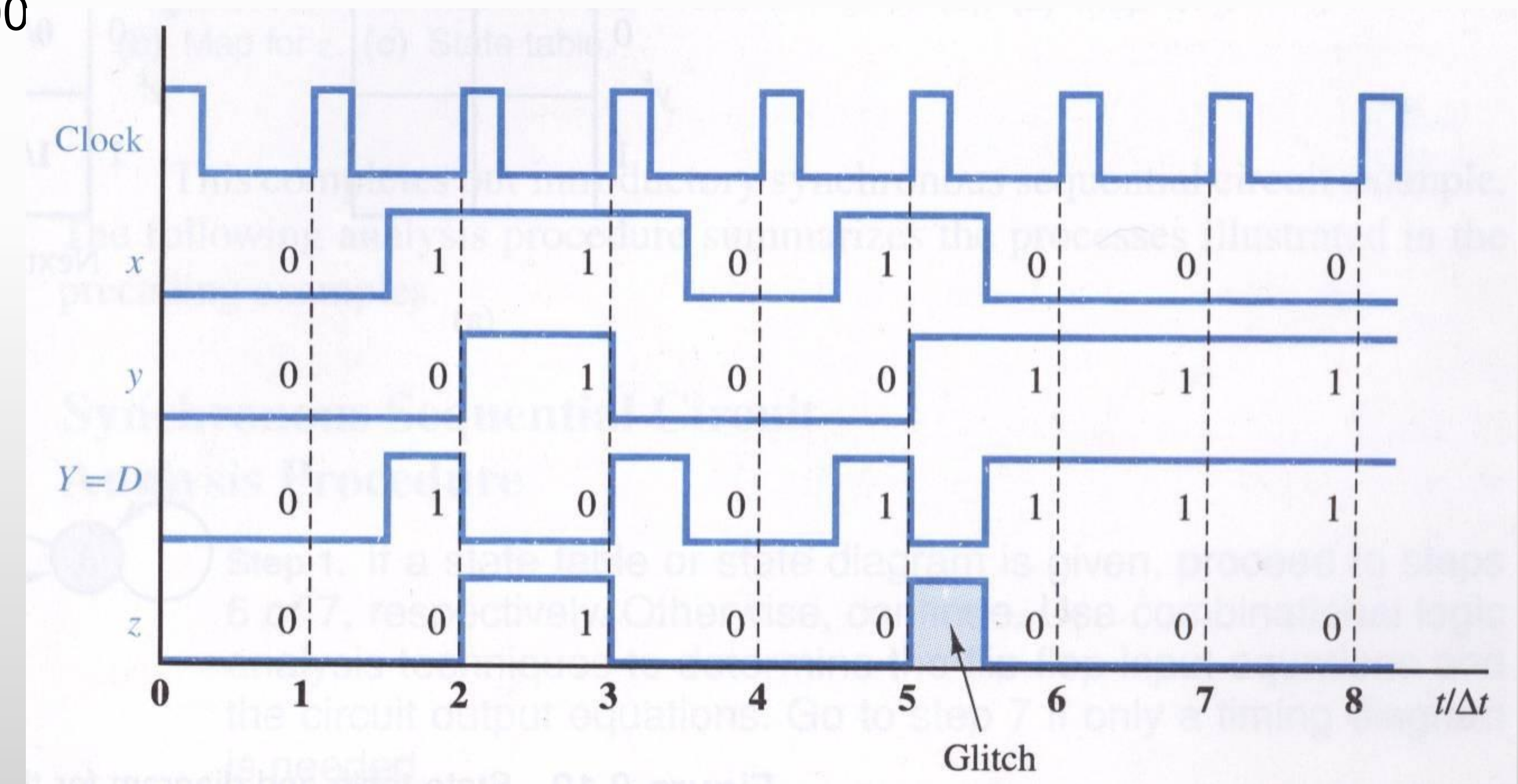


Analysis

$z = xy$

$Y = x\bar{y} + \bar{x}y = x \oplus y$

– Input sequence: x = 01101000



- Deriving state diagram and state table
  - Given circuit diagram ≡ Boolean equations
- Notation: y^k represents $y(k\,\Delta\,t)$
- k = integer; $\Delta\,t$ = clock period
- May assign numbers to states: 0 ≡ state A; 1 ≡ state B

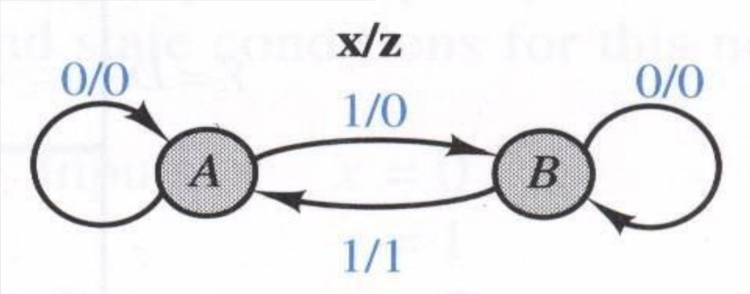
Present state y^k \ Input x^k	0	1
0		
1		

Present state y^k \ Input x^k	0	1
0	**0/0**	**1/0**
1	**1/0**	**0/1**

Next state/output

Present state \ Input x^k	0	1
A	***A*/0**	***B*/0**
B	***B*/0**	***A*/1**

Next state/output



Deriving state table from K-maps

$$z = xy$$

$$Y = x \oplus y$$

Evaluated at time $t = k\,\Delta t$

$$z^k = x^k \cdot y^k$$

$$Y^k = x^k \oplus y^k = y^{k+1}$$

y^k \ x^k	0	1
0	0	1
1	1	0

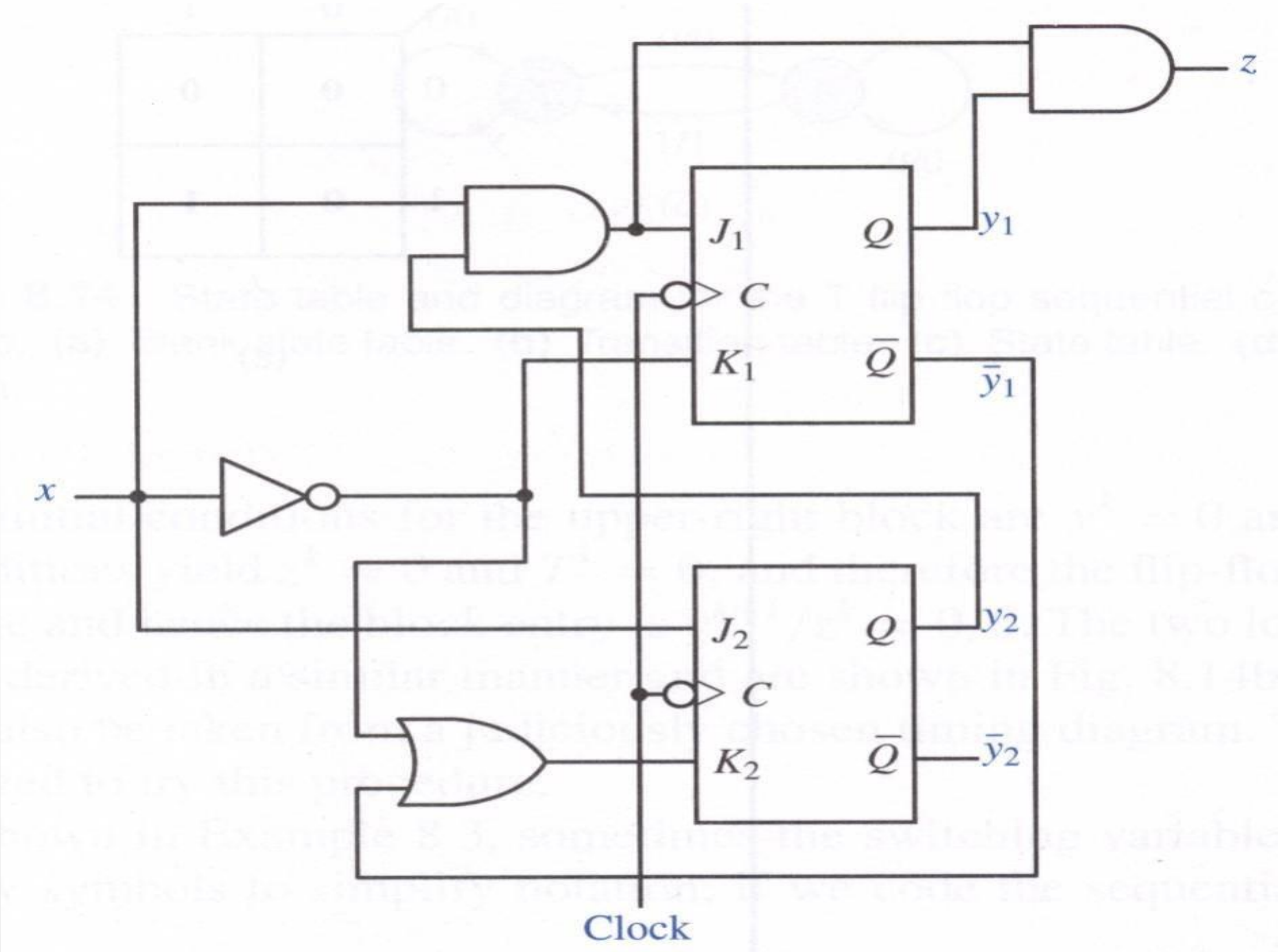
y^k \ x^k	0	1
0	0	0
1	0	1

Present state \ Input x^k	0	1
A	***A/0***	***B/0***
B	***B/0***	***A/1***

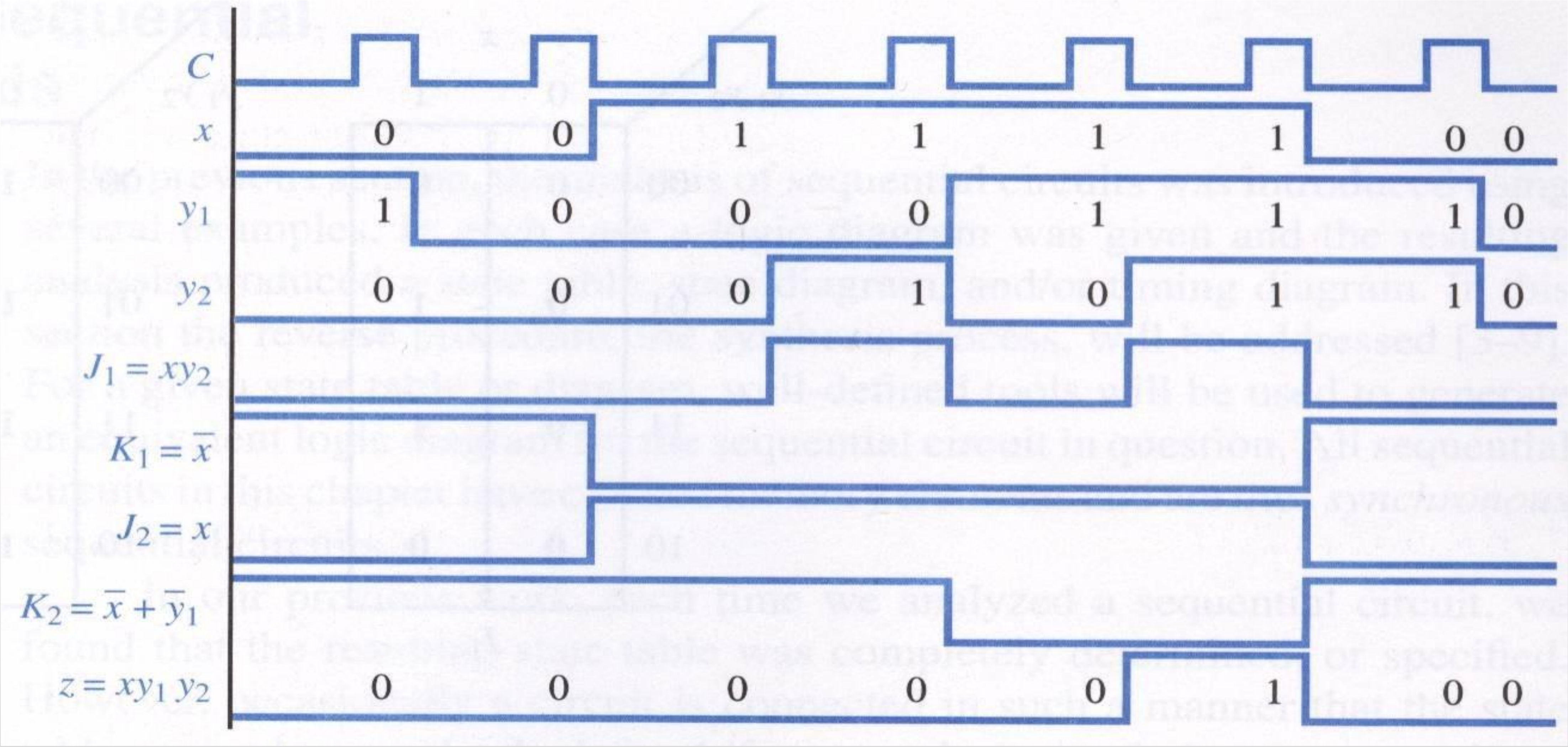
y^{k+1}/z^k

Analysis example

- Synchronous sequential circuit with flip- flops
  - Negative edge-
  - triggered
  - Inputs?
  - States?
  - Outputs?
  - Logic equations?



Timing Diagram



State table and K-maps

$y_1 y_2$ \ x	0	1
00	**00/0**	**01/0**
01	**00/0**	**10/0**
11	**00/0**	**11/1**
10	**00/0**	**11/0**

J_1

$y_1 y_2$ \ x	0	1
00	**0**	**0**
01	**0**	**1**
11	**0**	**1**
10	**0**	**0**

K_1

$y_1 y_2$ \ x	0	1
00	**1**	**0**
01	**1**	**0**
11	**1**	**0**
10	**1**	**0**

J_2

$y_1 y_2$ \ x	0	1
00	**0**	**1**
01	**0**	**1**
11	**0**	**1**
10	**0**	**1**

K_2

$y_1 y_2$ \ x	0	1
00	**1**	**1**
01	**1**	**1**
11	**1**	**0**
10	**1**	**0**

z

$y_1 y_2$ \ x	0	1
00	**0**	**0**
01	**0**	**0**
11	**0**	**1**
10	**0**	**0**

Combining the K- maps into state table

$y_1 y_2$	$x = 0$: $J_1 K_1$	$x = 0$: $J_2 K_2$	$x = 1$: $J_1 K_1$	$x = 1$: $J_2 K_2$
00	**01**	**01**	**00**	**11**
01	**01**	**01**	**10**	**11**
11	**01**	**01**	**10**	**10**
10	**01**	**01**	**00**	**10**

$y_1 y_2$	$x = 0$	$x = 1$
00	**00**	**01**
01	**00**	**10**
11	**00**	**11**
10	**00**	**11**

$Y_1 Y_2$

$y_1 y_2$	$x = 0$	$x = 1$
00	**00/0**	**01/0**
01	**00/0**	**10/0**
11	**00/0**	**11/1**
10	**00/0**	**11/0**

$Y_1 Y_2/z$

Thank You